AIntelia

Investigation of Off-shore Wind Energy Potential in Türkiye: A Case Study of Bandırma Bay

Erkan AKGÜN[1*], Harun ÖZBAY[2]
[1*]Department of Gönen Geothermal Energy Institute, Bandırma Onyedi Eylül University, Balıkesir, Türkiye, erkanakgun@gmail.com, ORCID: 0000-0003-1485-1642
[2]Department of Electrical Engineering, Faculty of Engineering and Natural Science, Bandırma Onyedi Eylül University, Balıkesir, Türkiye, hozbay@bandirma.edu.tr, ORCID: 0000-0003-1068-244X

In this study, the main factors in off-shore wind energy have examined and the current situation in the world and in Türkiye has presented. In addition, the pre-investment feasibility analysis for the planned offshore wind power plant facility in Türkiye and the steps to be followed have examined in detail. According to these plans, a case study has conducted for Bandırma Bay, which has high offshore wind energy potential. Hourly wind speed and direction data of the Bandırma Meteorological Station of the Meteorological Service between 2010 and 2020 were obtained. The analyzes carried out showed that the wind efficiency of the region is suitable for off-shore wind power plant installation. In addition, the most suitable location for the installation of the offshore wind power plant in Bandırma has been proposed.

Keywords: *Off-shore wind energy, off-shore installations, wind power plants.*

1. Introduction

The air movements known as wind are brought on by the forces that occur from the unequal heating and cooling of the planet. On the other side, wind energy is the kinetic energy of the air stream that generates the wind. Wind energy, which started to be used in the years before Christ, became the main power source for sailing ships in the seas, and windmills and windmills on land. This method has been used for many years to meet needs such as those related to wheat, corn milling, and water pumping. Using wind energy in BC. In the year 2800, it began in the Middle East. The utilization of wind energy by humanity has undergone a technological evolution from windmills to contemporary wind power facilities [1]. Wind energy has started to lose significance due to the development of the steam engine and the continuous generation of energy from fuels like wood and coal. Because fossil fuels are so inexpensive, wind energy was not given enough attention, but the 1970s oil crisis brought it back to people's attention. Wind farms in Europe and the USA are now considered modern engineering products in terms of economy, ecology, and energy because to improvements that occurred after 1980. With the introduction of Wind Turbines (RTs) in large quantities, wind power plants have been constructed, as have investments in this sector and advancements in the turbine. Wind farms, which were formerly constructed on land, are now constructed on water [2].

Offshore and onshore wind turbines have some technological differences. The specific outside protection layer created to shield them from corrosion in offshore systems is the first of these variations. Due to the high humidity and saline environmental conditions, as offshore systems are situated in the sea, a good external protection coating on the wind turbine surface is essential. The entire system, notably the blade design, is made to be quieter because onshore wind turbines might be placed close to residential areas. On the other hand, the primary goal of the design for offshore wind turbines is to achieve maximum aerodynamic efficiency as opposed to noise. Therefore, compared to onshore systems, offshore wind turbines have faster blade speeds. The following requirements also come with faster blade speeds [3].

- The area that the wing sweeps diminishes as a result of the wing's reduced stiffness, shortening the wing's overall length.
- Because the blade's swept area is decreasing, the forces acting on it when the wind turbine is not in use are reduced.

- Mechanical components like gearboxes and main bearings can shrink (applicable in case of gear box systems) [4]

Periodic maintenance of offshore wind turbines using gear box is also slightly different from onshore systems. The service time of the lubrication system is longer. Many bearings are automatically lubricated. A special oil filtering system in the gear box ensures that the quality of the oil is maintained for a long time. The most important cost parameters of the offshore WPP are the foundation construction of the turbines and the transmission lines drawn under the sea to the nearest land part. The cost of offshore WPPs is determined by the distance of the facility to land and the depth at which it will be installed. Because these factors are the main factors that determine the basic and transmission connection costs. The investment cost distribution of offshore WPPs is slightly different from onshore WPPs. For example, in an onshore wind turbine, 68% of the investment cost is wind turbine and 9 percent is foundation construction; In offshore systems, these rates are distributed as 33% and 24%. In addition, the total investment costs of offshore RES are higher than onshore systems. The first offshore wind power plant is the Vindeby wind power plant, which has an installed capacity of 5 MW, established near Looland Island in Denmark [5]. In the first phase, offshore wind power plants were established in areas not exceeding 10 kilometers from the coast and 10 meters in depth.

Onshore and offshore wind power plants differ significantly in a few key ways;

- ✓ More energy can be produced in offshore regions due to the presence of more stable and higher wind speeds.
- ✓ Installation cost of offshore wind power plants is higher than onshore systems. For this reason, they are mostly preferred in plantts of 50 MW and above.
- ✓ Operation and maintenance costs are higher and more difficult in offshore wind power plants.
- ✓ Various logistics problems arising from sea conditions may be encountered in offshore wind power plants [6].

While conducting feasibility studies for an offshore WPP, these differences mentioned above must be taken into account. In addition to the differences between the systems above, some basic parameters should also be examined during the feasibility studies;

- Offshore wind energy potential
- Sea depth
- Distance to the shore
- Military use
- Fishing
- Marine traffic
- Pipelines and cabling [7]

Due to its geographic location, Türkiye has both onshore and offshore wind energy potential that attracts interest. According to the World Bank report "Globalization: Expanding Offshore Wind to Growing Markets," Türkiye has a total of about 69 GW, with 12 GW located in places with less than 50 meters of ocean depth and 57 GW located in depths between 50 and 1,000 meters. There is a chance for offshore wind power [8]. According to the analysis, offshore wind power plant (OWPP) investments are ideal for the wind speeds in the Aegean, Black, and Marmara seas. When compared to the total installed power of wind power plants, OWPP only makes up a small portion; nonetheless, OWPP investments have steadily expanded, particularly over the past ten years, thanks to technological advancements, declining investment prices, and effective support initiatives. Facilities that use wind energy to produce electricity are still quite expensive when measured in terms of original installation costs. In order to do cost analyses prior to the construction of wind energy-generating facilities, it is crucial to assess the wind energy potential at the installation location. The transition from the installation of terrestrial WPPs to the construction of sea-based power plants is supported by a number of technical and social considerations. Higher average wind speeds above sea level and lower levels of turbulence to which turbines are exposed are two of the most crucial technological variables [9]. There is more energy potential in the seas since the amount of energy that can be produced directly correlates with wind speed.

2. Investment and Operating Expenses

A high degree of accuracy must be maintained when measuring various technical values in order to build and develop WPPs (onshore or offshore) in a healthy manner, especially during the plant's feasibility phase. Both meteorological and oceanographic characteristics should be measured for the creation of OWPPs [10]. The location of the power plant, the choice of the turbine type for the site, the configuration of the turbines inside the power plant, and the estimation of the potential energy to be produced are all influenced by meteorological considerations. The two types of platforms most frequently utilized for measuring offshore winds are fixed-foundation masts and floating measurement stations placed at sea. As the water depth rises, it becomes more difficult to erect fixed-foundation measuring masts economically [11]. Compared to fixed-base measuring poles, installing floating measuring stations is significantly simpler and less expensive. More crucially, by taking wind measurements at multiple locations and relocating the stations to new locations after the measurements are finished at specific times within the borders of the proposed power plant, it is feasible to better understand the local wind conditions.

The investment costs of OWPP are impacted by numerous aspects;

- The plant's dimensions.
- Variable local conditions, such as sea depth.
- The distance from the shore to the power plant.
- Access to the grid.
- Localized wave height
- Supply-chain limitations (eg supply of installation ships, problems in finding skilled workers).
- Prices of commodities and energy.
- Exchange.
- Suppliers of equipment and installation businesses use various pricing techniques [12].

3. Challenges for Offshore WPP Development in Türkiye

Technical and administrative studies should be carried out to develop an infrastructure so that the required technology can be used in our country, even though the OWPP has not yet been founded in Türkiye [10]. There are a few things that need be considered in the regions where OWPP projects will be developed. Some of the most important factors include the area's wind energy potential, the shape and depth of the sea, the distance to the beach, and environmental and social concerns. The planned OWPP project region must also not be near a military no-fly zone, interfere with the continental shelf, or cause obstructions to fishing or maritime trade. The Sea of Marmara and the Turkish Aegean region have the highest offshore wind potential. Although the sea levels in both locations have quickly risen, it is possible to install floating-based turbines rather than fixed-base ones in suitable locations.

4. The Potential and Current Situation of Bandırma Bay

In the southern part of the Marmara Sea is Bandırma. In Bandırma Bay, the main winds are from the north-northeast. In the northeast of Bandırma Bay, as depicted in Figure 1, there is a shooting range and military training facility. It is situated between the Kapıdağ Peninsula's east-west oriented coast and the South Marmara Section's northeast-southwest oriented shore.

Its width is 11 km from the Kapsalı (Kapsala) Cape in the northeast to the coasts of Yenice village in the southeast, and it is 15 km from the south of Aşağıyapıcı village to Fener Island. Its deepest point (55 m) is located 3 km northwest of the town of Dutliman. Winds from the east and northeast can enter the bay, but winds from the northwest, west, and southwest cannot. The wind turbine settlement shown in Figure 2 has been determined to be appropriate for Bandera Bay after analysis.

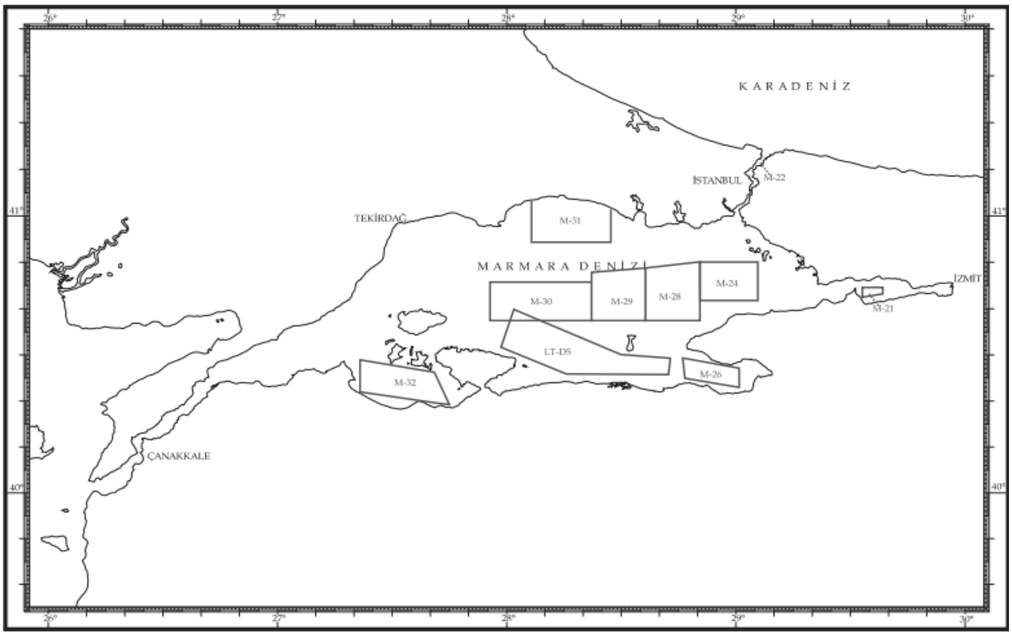


Figure 1. *Marmara Sea Training and Shooting Fields*

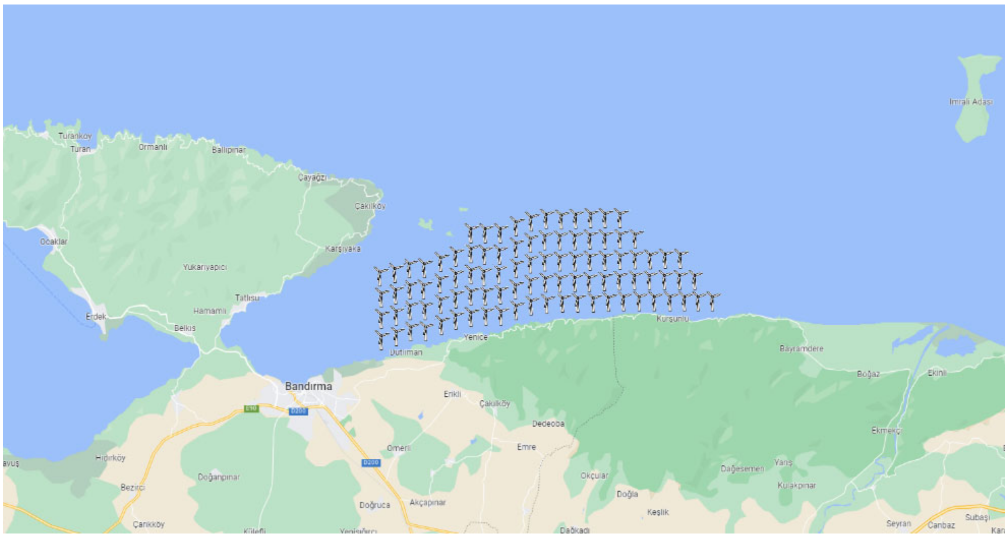
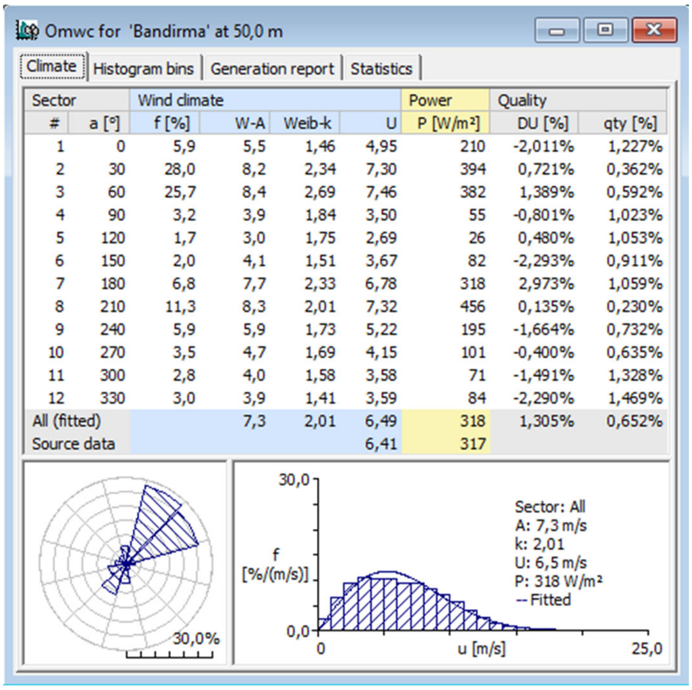


Figure 2. *Bandırma Bay Wind Turbine Settlement*

5. Case Study of Bandırma

In this study, the Meteorological Service provided hourly wind speed and direction data for Bandırma meteorological sites between 2010 and 2022. The data has been transformed using a macro since it cannot be input directly into the application as it is received. Figure 3 displays the outcome of the program's analysis of the wind data. This indicates that Sector 2 (30°) is the predominant wind direction in Bandırma, which is southwest. The average wind speed for all sectors is 7.3 m/s, and the power density is 318 W/m^2.



Sector		Wind climate				Power	Quality	
#	a [°]	f [%]	W-A	Weib-k	U	P [W/m²]	DU [%]	qty [%]
1	0	5,9	5,5	1,46	4,95	210	-2,011%	1,227%
2	30	28,0	8,2	2,34	7,30	394	0,721%	0,362%
3	60	25,7	8,4	2,69	7,46	382	1,389%	0,592%
4	90	3,2	3,9	1,84	3,50	55	-0,801%	1,023%
5	120	1,7	3,0	1,75	2,69	26	0,480%	1,053%
6	150	2,0	4,1	1,51	3,67	82	-2,293%	0,911%
7	180	6,8	7,7	2,33	6,78	318	2,973%	1,059%
8	210	11,3	8,3	2,01	7,32	456	0,135%	0,230%
9	240	5,9	5,9	1,73	5,22	195	-1,664%	0,732%
10	270	3,5	4,7	1,69	4,15	101	-0,400%	0,635%
11	300	2,8	4,0	1,58	3,58	71	-1,491%	1,328%
12	330	3,0	3,9	1,41	3,59	84	-2,290%	1,469%
All (fitted)			7,3	2,01	6,49	318	1,305%	0,652%
Source data					6,41	317		

Figure 3: Offshore Turbine Foundations

6. Conclusion

Türkiye is well-suited for the implementation of facilities that generate electricity using wind energy because of its location and geographic makeup. According to this study, Bandırma is the ideal place to build wind turbines due to its wind potential and installation area. Bandırma Bay has a high wind energy potential, especially in terms of OWPP. According to this result, the prevailing wind direction in Bandırma is southwest, which is Sector 2 (30°). The power density is 318 W/m2 and the wind speed is 7.3 m/s for the average of all sectors. The completion of the required feasibility studies and the expansion of government incentives are required to capitalize on this potential.

REFERENCES

[1] M. Ö. Ültanır, “Yeldeğirmeninden Günümüze Rüzgar Enerjisi”, Bilim ve Teknik Dergisi,” p. Sayı 341, s.56–61, Ankara, 1996.

[2] TUSIAD, “21. yy. Girerken Türkiye’nin Enerji Stratejisinin Değerlendirilmesi,” *TUSİAD-T/98-12/239*, 1998.

[3] M. Durak and S. Özer, “Rüzgar Enerjisi: Teori ve Uygulama,” 2007.

[4] M. Durak and S. Özer, “Rüzgar Enerjisi: Teori ve Uygulama,” *Ankara*, pp. 479, 481, 485, 2008.

[5] D. Infield, “Offshore Wind Power,” in *Transition to Renewable Energy Systems*, Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, 2013, pp. 265–281. doi: 10.1002/9783527673872.ch15.

[6] İ. YAVUZ and H. ÖZBAY, “Rüzgar Türbinlerinde Kurulum ve Bakım Süreçleri: Bandırma Örneği,” *Mühendislik Bilim. ve Araştırmaları Derg.*, vol. 2, no. 2, pp. 58–68, Oct. 2020, doi: 10.46387/bjesr.800527.

[7] S. A. Kocaturk and Y. Unsan, “Rüzgar Enerji Santrallerinin Tarihsel Gelişimi ve Açık Deniz Rüzgar Enerji Santrallerinin Tarihsel Gelişimi,” *GIBD - Dergi*, 2015.

[8] ESMAP, “Going Global-Expanding Offshore Wind to Emerging Markets,” *World Bank*, no. October, pp. 1–44, 2019, [Online]. Available: http://documents1.worldbank.org/curated/en/716891572457609829/pdf/Going-Global-Expanding-Offshore-Wind-To-Emerging-Markets.pdf

[9] L. Serri, L. Colle, B. Vitali, and T. Bonomi, “Floating Offshore Wind Farms in Italy beyond 2030 and beyond 2060: Preliminary Results of a Techno-Economic Assessment,” *Appl. Sci. 2020, Vol. 10, Page 8899*, vol. 10, no. 24, p. 8899, Dec. 2020, doi: 10.3390/APP10248899.

[10] B. H. Bailey, M. Filippelli, and M. Baker, “Metocean Data Needs Assessment for U.S. Offshore Wind Energy,” Jan. 2015, doi: 10.2172/1338823.

[11] M. Durak, “Denizüstü Rüzgar Elektrik Santral (Dres) Projeleri İçin Rüzgar Ölçümleri,” 2019.

[12] W. Musial and J. Nunemaker, “NOTICE 2018 Offshore Wind Technologies Market Report Primary Authors,” *US DOE Off. Energy Effic. Renew. Energy*, 2018.